(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号
特開2000－321134
（P2000－321134A）
(43)公開日　平成12年11月24日(2000.11.24)

| (51)Int.Cl.⁷ | | 識別記号 | FI | | テーマコード゛(参考) |
|---|---|---|---|---|---|
| Ｇ０１Ｊ | 3/10 | | Ｇ０１Ｊ | 3/10 | ２Ｇ０２０ |
| | 3/26 | | | 3/26 | ２Ｋ００２ |
| Ｇ０２Ｆ | 1/39 | | Ｇ０２Ｆ | 1/39 | |

審査請求　未請求　請求項の数６　ＯＬ　（全　５　頁）

(21)出願番号　特願平11－135199

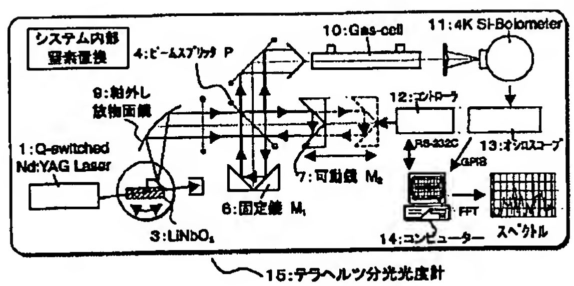
(22)出願日　平成11年５月17日(1999.5.17)

(71)出願人　000118213
伊藤　弘昌
宮城県仙台市青葉区荒巻字青葉390番82号
(72)発明者　伊藤　弘昌
宮城県仙台市青葉区荒巻字青葉390－82
(72)発明者　菅原　郷史
宮城県仙台市若林区上飯田３－35－22
(72)発明者　陳　キュウ
宮城県仙台市青葉区福沢町４－10　101号室

Fターム(参考)　2G020 AA02 CA12 CB05 CB14 CB23
CB27 CB46 CC22 CC54 CD04
CD16 CD24 CD35 CD52
2K002 AA04 AB12 CA03 HA21

(54)【発明の名称】　テラヘルツ分光光度計

(57)【要約】
【課題】　強いスペクトル強度をもつ波長可変テラヘルツ波光源と、二光束干渉を用いたマーチンーパプレット型フーリエ干渉計を組み合わせることにより、ＴＨｚ領域での分光を、Ｓ／Ｎ良く測定できる分光光度計を提供する。
【解決手段】　非線形結晶ＬｉＮｂＯ₃３をＮｄ：ＹＡＧレーザー１で励起することにより発生したＴＨｚ波をＳｉプリズム２を用い空間に放射し軸外し放物面鏡９によりコリメートするＴＰＧ光源と、このＴＨｚ波をビームスプリッター４により二光束に分割した後、固定鏡Ｍ₁６と可動鏡Ｍ₂７により再び重ねられ干渉させるＭＰ型干渉計、また分光の為の資料が充填されたガスセル１０や ＴＨｚ波を検出する為の４Ｋ－Ｓｉボロメータ１１等、これらを具備したテラヘルツ分光計１５を構成した。



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【特許請求の範囲】

【請求項１】　非線形光学効果であるパラメトリック発生（ＰＧ）により得られる波長可変テラヘルツ波（以下テラヘルツパラメトリック発生：ＴＰＧと省略）を光源として用いることを特徴とする分光計。

【請求項２】　請求項１において、非線形結晶としてＬｉＮｂ$O_3$やＬｉＴａ$O_3$等を用い、近赤外の光源で励起することにより発生するテラヘルツ（以下ＴＨｚと省略）波を小型かつ強力な遠赤外領域での光源とすることを特徴とする分光計。

【請求項３】　請求項２において、非線形結晶内より生ずるＴＨｚ波の中心波長を、前記励起光源の結晶への入射角度を変化させることにより可変させることが可能な光源をもつことを特徴とする分光計。

【請求項４】　請求項２において、非線形結晶からのＴＨｚ波の大気中への取り出しに、Ｓｉ製のプリズムを用いることにより、励起光源の結晶への入射角度を変えてもほぼ一方向にＴＨｚ波が出射される特徴を持つ光源をもつことを特徴とする分光計。

【請求項５】　強いスペクトル強度をもつ波長可変ＴＰＧ光源と、二光束干渉を用いた分光器を組み合わせることを特徴とする小型高輝度テラヘルツ分光光度計。

【請求項６】　請求項５において、干渉計にサブミリ波領域での効率の良い透過特性を持つワイヤーグリッドをビームスプリッターに用いたマーチンーパプレット型フーリエ干渉計（以下ＭＰ型干渉計と省略）を用いる分光計。

【発明の詳細な説明】

【０００１】

【発明の所属する技術分野】本発明は、非線形光学効果であるパラメトリック発生により得られる強いスペクトル強度をもつ波長可変ＴＰＧ光源と、二光束干渉を用いた分光器を組み合わせることにより実現される、小型高輝度テラヘルツ分光光度計に関するものである。

【０００２】

【従来の技術】遠赤外領域の分光には、従来、連続的な周波数成分を持つ高圧水銀灯がほとんど唯一の光源として用いられており、分光計としては光量の有効利用の点で有利な、二光束干渉を用いたフーリエ変換分光計（以下ＦＴＳと省略）が広く用いられている。これは干渉光強度が光源スペクトルの波数空間から実空間へのフーリエ変換に対応していることを利用したものである。ＦＴＳでは、光源から光をビームスプリッターにより二光束に分け、二光束間に光路差を作り出した後干渉させ、その干渉曲線からスペクトルを得ているが、その二光束を得る方法により、ＦＴＳ種類は、振幅分割により二光束を得るマイケルソン型、波面分割により二光束を得るラメラー型、および偏光を利用して二光束を得るマーチンーパプレット型の３種に大別される。この中でサブミリ領域マイケルソン型ＦＴＳの半透明鏡の効率が落ちる為、効率の良い透過特性を持つＭＰ型干渉計が多く利用されている。

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【０００３】

【発明が解決しようとする課題】従来の遠赤外分光では、光源である高圧水銀灯のスペクトル強度が低いため、インターフェログラム情報がノイズを多く含み、全体的なＳ／Ｎ比が低下してしまうという欠点がある。このＴＨｚ領域（０．５～５ＴＨｚ）での分光を、Ｓ／Ｎ良く測定できることを目的とする。

【０００４】

【課題を解決する為の手段】上記課題を解決する為に、本発明は、次のようなテラヘルツ分光光度計を採用した。即ち、請求項1記載の、パラメトリック発生により得られる波長可変ＴＰＧを光源として用い、それを請求項5にあるように、二光束干渉を用いた分光器と組み合わせることにより実現される、小型高輝度テラヘルツ分光光度計である。光源は、請求項2記載の非線形結晶ＬｉＮｂ$O_3$やＬｉＴａ$O_3$等を近赤外の光源で励起することにより発生するＴＰＧを用いた。これは、広い遠赤外領域で波長可変でありｎｓｅｃ幅のパルスであるために比較的強い強度と長い光路長、ブロードなスペクトル特性を持つことから、分光に有利な特徴を有しており、小型かつ強力な遠赤外領域での光源となり得る。更に分光の方式としては、遠赤外領域での光量の有効利用を考えると二光束干渉を用いたフーリエ分光計が望ましく、中でもとくにサブミリ波領域での効率の良い透過特性を持つ請求項6記載のＭＰ型干渉計の構成を用いた。

【０００５】

【発明の実施の形態】以下、図面を参照して、本発明の形態について説明する。この発明は、請求項５に記載してあるように、波長可変ＴＰＧ光源と、ＭＰ型干渉計を組み合わせることで実現される小型高輝度テラヘルツ分光光度計である。ここで、それぞれの原理を示す。

A. ＴＨｚ波パラメトリック発生（ＴＰＧ）の発生原理

光パラメトリック相互作用においては、ポンプ波（$\omega_P$）$\omega_P$を請求項２記載の非線形光学結晶に入射するとシグナル波（$\omega_T$）およびアイドラー波（$\omega_i$）がエネルギー保存則$\omega_P = \omega_T + \omega_i$に従って発生する現象であり、シグナル波$\omega_T$の周波数をＴＨｚ波帯にまで拡張することにより、分光に適した幅広いスペクトルを持つ光源を提供することが可能となる。請求項１記載のパラメトリック相互作用を用いた光波の波長変換によってＴＨｚ波発生を行なうとき、純粋な光波だけの相互作用を用いた場合には利得が小さく、ＴＨｚ波帯の動作が困難である。しかし、前記ＬｉＮｂ$O_3$やＬｉＴａ$O_3$などラマン活性かつ赤外光活性な該非線形光学材料を用いると、物質の素励起波（ポラリトン）を介して強い相互作用を起こすことができる。図1に示すようにポラリトンは低エネルギー領域ではフォトン的な振舞いするため、請求項２記載の十分強い励起光源を用いれば、ポラリトンを

介した誘導散乱現象を引き起こし高効率なＴＨｚ波（$\omega_T$）発生が可能である。図2にＴＰＧ実験の概要図を示す。結晶内にポンプ光を入射したとき入射端で発生した量子雑音（熱雑音）が結晶利得により増幅され、ポンプ光から周波数がシフトした光（アイドラ光）が出力される。そしてポンプ光とアイドラ光がエネルギー保存則（$\omega_P = \omega_i + \omega_T$）と運動量保存則（$k_P = k_i + k_T$）を満たしたところでＴＨｚ波が発生する。発生するＴＨｚ波は受光角に依存した幅広いスペクトル（約１５ｃｍ$^{-1}$）を持ち、結晶の入射角を変化させることにより中心波長を同調できる。図3はノンドープＬｉＮｂＯ$_3$結晶を波長１．０６４μｍにより励起した場合の利得の計算結果であり、１５０～４００μｍ程度の領域に高い利得をもつことがわかる。ポンプ光強度Ｉ$_P$とともに利得係数が増大する特性は、利得がＩ$_P$の平方根に比例することに起因している。また、低温領域において利得係数が増大する特性は、主としてＴＨｚ波帯での吸収係数の減少に起因している。

Ｂ．マーチンーパプレット型干渉計の原理

請求項６記載のＭＰ型干渉計の構成を図4に示す。前記ＭＰ型干渉計では入射光の偏光方向を分割して二つの光束をつくる偏光分割方式を用いる。請求項６記載のワイヤグリッドは、その該ワイヤに対して平行な偏光方向の電磁波を反射し、垂直な電磁波を透過させる（図５）。つまり、電磁波の偏光方向に対して前記ワイヤグリッドを４５°に傾けることにより入射電磁波の反射：透過を１：１にすることが可能であり、効率のよい電磁波の分割が出来るという特徴を持つ。入射するＴＨｚ波の偏波方向は紙面と垂直である。４５°においた前記ワイヤグリッドの請求項６記載のビームスプリッタＤによりＴＨｚ波は１：１に分けられる。反射光と透過光はそれぞれ固定鏡と可動鏡により反射されて、偏光方向が９０°回転される。再びＤで結合したＴＨｚ波はポラライザＰ（ワイヤグリッド）によって該ワイヤに平行な成分と垂直な成分に分けられる。前記ビームスプリッタに入射する電界は、

【数式1】

$$E_i = e_n \frac{a}{\sqrt{2}} \cos \omega t + e_t \frac{a}{\sqrt{2}} \cos \omega t \quad \cdots (1)$$

再び前記ビームスプリッタで結合した電界は

【数式2】

$$E_f = e_n \frac{a}{\sqrt{2}} \cos(\omega t + \Delta_A) + e_t \frac{a}{\sqrt{2}} \cos(\omega t + \Delta_B) \quad \cdots (2)$$

となり、前記ポラライザＰから出射するとその振幅は次のようになる。

【数式3】

$$|E| = \frac{a}{2} (\cos(\omega t + \Delta_A) - \cos(\omega t + \Delta_B)) \quad \cdots (3)$$

ただし、$\Delta_A$、$\Delta_B$はそれぞれの位相変化であり、その強度は

【数式4】

$$I_P = \langle |E|^2 \rangle = \frac{a^2}{4}(1 - \cos\Delta) = \frac{I_0}{2}(1 - \cos\Delta) \quad \cdots (4)$$

となる。ここで$\Delta = 2\pi\sigma x$、xは光路差、σは波数である。そのスペクトル強度をＢ（σ）とすると、すべてのσについて積分することにより、全強度は

【数式5】

$$I(x) = \frac{1}{2}\int_0^\infty B(\sigma)(1 - \cos 2\pi\sigma x)d\sigma \quad \cdots (5)$$

となる。光路差ｘを変えると、強度Ｉ（ｘ）が変化する。この干渉波形はインターフェログラムと呼ばれ、得られたインターフェログラムをフーリエ変換すると、スペクトルＢ（σ）が求められる。本発明のテラヘルツ分光光度計はこのようなフーリエ分光法にも基づくため、多くの周波数成分を同時に測定できる利点がある。

【０００６】

【実施例】これまでに述べたＴＰＧ光源とＭＰ型干渉計を組み合わせることにより、スペクトル強度の大きなテラヘルツ分光光度計が実現できる。ＭＰ型分光計の透過特性は請求項6記載のワイヤグリッドの反射透過特性に大きく依存する。前記ビームスプリッタとして使うワイヤグリッドはワイヤの間隔をｇとすると４ｇ以下の波長では効率が落ちる。本発明の請求項１記載のＴＰＧによるＴＨｚ波波長は３３ｃｍ$^{-1}$～７１ｃｍ$^{-1}$（１４０μｍ～３１０μｍ）の帯域であるので、本発明の分光システムはまずこの領域を測定でするように、ワイヤ間隔ｇ（μｍ）が３５μｍ以下が必要である。前記ワイヤグリッドは、直径が１０μｍ、格子間隔がそれぞれ２５μｍおよび３０μｍのタングステン線より構成されたもので、格子面有効直径が９０ｍｍである。請求項１のＴＰＧより発生したＴＨｚ光源のビーム直径は約５ｍｍ、広がり角度約１．５°、前記ビームスプリッタの位置ではビーム直径が約１５ｍｍであるので、十分な有効面積を持つ。図６に本発明のテラヘルツ分光光度計のシステム構成を示す。ＴＨｚ波発生に用いた請求項1のＴＰＧ光源は、請求項２記載の近赤外のレーザーとしてＮｄ：ＹＡＧレーザー（パルスエネルギー１２ｍＪ、パルス幅７ｎｓ）で励起し、発生したＴＨｚ波は請求項４記載のＳｉプリズムを用い空間に放射され、軸外し放物面鏡によりコリメートしたあとポラライザＰ$_1$で直線偏光にして、請求項6記載のＭＰ型干渉計に導く。 固定鏡Ｍ$_1$と可動鏡Ｍ$_2$に用いた反射鏡は直角プリズムを二枚組合わせた直角反射鏡を用いており、アルミニウムのコーティングを施している。これにより入射電磁波を常に入射方向に戻すことができるように調整されている。この反射光は入射光の偏波と直行する偏波を持つので、ビームスプリッタにより再び重ねられる。可動鏡を駆動させるアクチュエータは、最小移動間隔１０μｍ、最大移動距離２０ｃｍである。干渉したＴＨｚ波の検出には請求項７記載の感度の高い４Ｋ－Ｓｉボロメータを使用した。

可動鏡を走査することにより得られる信号波形（インターフェログラム）をフーリエ変換することによって、スペクトル情報を得る。本発明のテラヘルツ分光光度計システムは機器制御用ソフトを用いて、可動鏡の走査および検出器の出力データの自動取り込みを行った。インターフェログラムの測定手順は、次の通りである。始めに、可動距離およびサンプリング間隔を入力し、分解能および波数の領域を決める。次にコンピュータから命令を送り、可動鏡をサンプリング開始位置$x_i$まで動かし、鏡が$x_i$に着いた後、検出器からの出力をオシロスコープを通しコンピュータに取り込む。その後、再び可動鏡を次の位置$x_{i+1}$まで動かした後、始めの可動鏡のサンプリング開始位置$x_i$を$x_{i+1}$おきかえてその後の工程を必要回数繰り返しインターフェログラムを得る。以上の測定およびインターフェログラムのフーリエ変換はいずれもコンピューター上で処理し、スペクトル情報を得ている。

【０００７】

【発明の効果】以上説明したように、本発明のテラヘルツ分光光度計の測定例を示す。スペクトル測定の最大分解能を得るには、最大光路差が得られるように光路差０の位置を始点としてインターフェログラムを測定すれば良い。図７は大気中で測定したＴＨｚ波のインターフェログラムの一例である。 本測定では、最大１００$cm^{-1}$（３ＴＨｚ）付近までの測定を行うために、サンプリング間隔を$\Delta X = 40\mu m$（最大波数１２５$cm^{-1}$）に設定した。また最大光路差は１ｃｍに設定し、これに対応する分解能は０．５$cm^{-1}$（１５ＧＨｚ）である。図８はインターフェログラムのフーリエ変換により得られたスペクトルであり、全体の包絡線がＴＨｚ光源のスペクトル強度を与える。この前記ＴＰＧの中心波長は０．５～５ＴＨｚの範囲で同調が可能である。

【０００８】このように、従来光源のスペクトル強度が不足することがさけられなかった０．５～５ＴＨｚ帯での分光で、ＴＨｚ帯パラメトリック発生光を光源としたＭＰ型テラヘルツ分光光度計システムをもってして、ＴＨｚ波帯における高分解能な分光を可能たらしめる一技術となり得る。

【図面の簡単な説明】

【図１】ポラリトンの分散関係と位相整合曲線を表す図である。

【図２】ＴＨｚパラメトリック発生実験の構成図である。

【図３】パラメトリック利得の周波数特性を示す図である。

【図４】マーチンーパプレット型干渉計の構成図である。

【図５】ワイヤグリッドの偏光特性を示す図である。

【図６】テラヘルツ分光光度計の全体の構成図である。

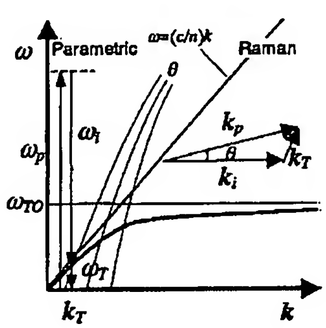
【図７】テラヘルツ分光光度計により大気中計測したＴＨｚ波のインターフェログラムの図である。

【図８】コンピューターによるフーリエ変換後のスペクトルを示す図である。

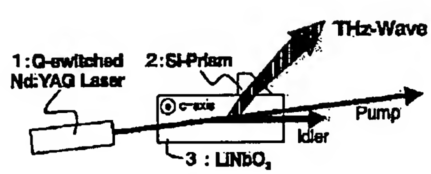
【符号の説明】

１　励起レーザー
２　結合器
３　非線形結晶
４　分配器
５　偏光版
６　固定鏡
７　稼動鏡
８　ワイヤー
９　コリメート用非対称球面ミラー
１０　分光用資料
１１　検出器
１２　稼動鏡用コントローラー
１３　オシロスコープ
１４　システム制御用コンピューター
１５　テラヘルツ分光光度計

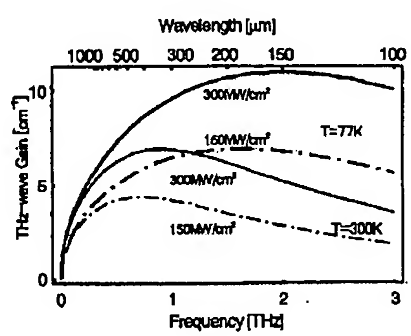
【図１】



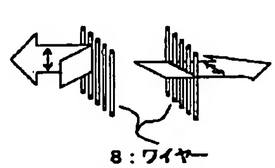

【図２】



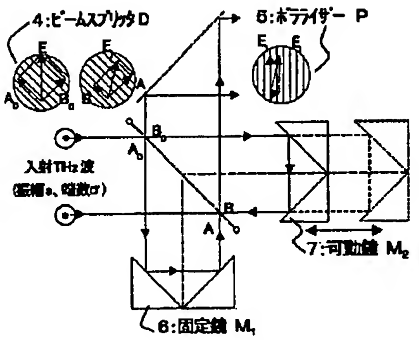

【図３】



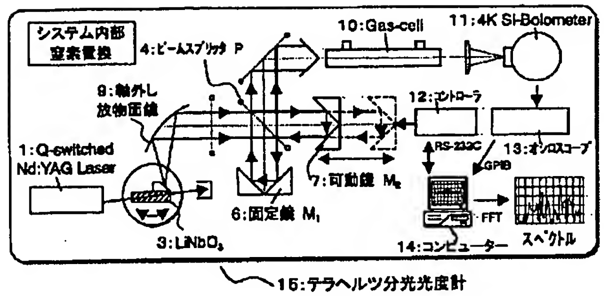

【図５】



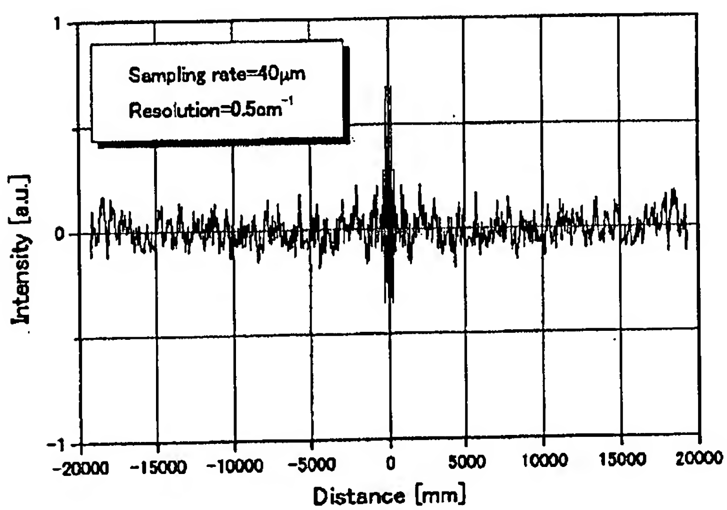
【図4】


4:ビームスプリッタ D
5:ポラライザー P
入射THz波
7:可動鏡 $M_2$
6:固定鏡 $M_1$

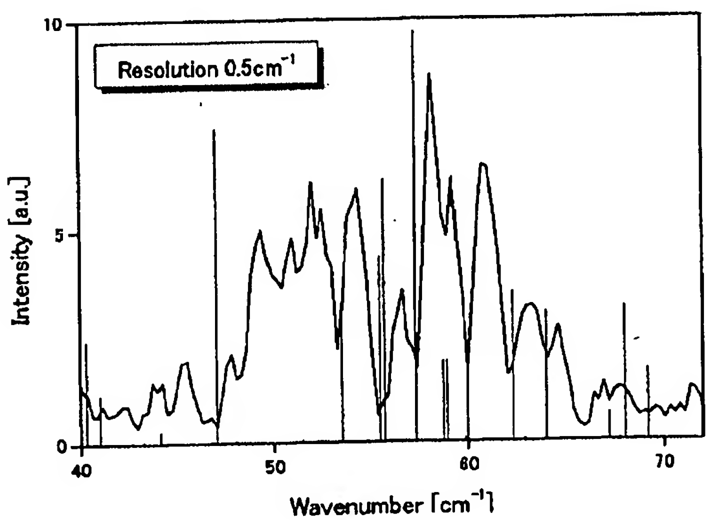
【図6】


システム内部
窒素置換
4:ビームスプリッタ P
10:Gas-cell
11:4K Si-Bolometer
9:軸外し
放物面鏡
12:コントローラ
1:Q-switched
Nd:YAG Laser
RS-232C
13:オシロスコープ
GPIB
7:可動鏡 $M_2$
6:固定鏡 $M_1$
FFT
3:$LiNbO_3$
14:コンピューター
スペクトル
15:テラヘルツ分光光度計

【図7】


Sampling rate=40μm
Resolution=0.5cm⁻¹
Intensity [a.u.]
1
0
-1
-20000
-15000
-10000
-5000
0
5000
10000
15000
20000
Distance [mm]

【図8】


Resolution 0.5cm⁻¹
Intensity [a.u.]
10
5
0
40
50
60
70
Wavenumber [cm⁻¹]

| | |
|---|---|
| **PAT-NO:** | JP02000321134A |
| **DOCUMENT-IDENTIFIER:** | JP 2000321134 A |
| **TITLE:** | TERA HERTZ SPECTROPHOTOMETER |
| **PUBN-DATE:** | November 24, 2000 |

## INVENTOR-INFORMATION:

| NAME | COUNTRY |
|---|---|
| ITO, HIROMASA | N/A |
| SUGAWARA, GOSHI | N/A |
| CHIN, KYU | N/A |

## ASSIGNEE-INFORMATION:

| NAME | COUNTRY |
|---|---|
| ITO HIROMASA | N/A |

**APPL-NO:** JP11135199

**APPL-DATE:** May 17, 1999

**INT-CL (IPC):** G01J003/10 , G01J003/26 , G02F001/39

## ABSTRACT:


PROBLEM TO BE SOLVED: To provide a spectrophotometer which can measure spectroscopy in THr(tera Hertz) region with good S/N by combining a variable wavelength tera Hertz wave light source having high spectral strength with a Type Fourier interferometer.

SOLUTION: The tera Hertz spectrometer 15 comprises a TPG(tera Hertz **parametric** generation) light source for radiating a **THz** wave generated by pumping a nonlinear **crystal** $LiNbO_3$ 3 through an Nd:YAG laser 1 into the space using an Si prism and collimating it through an off-axis parabolic mirror 9, an MP type interferometer for splitting

the **THz** wave through a beam splitter 4 into two light beams and causing interference by superposing them again by means of a fixed mirror M16 and a movable mirror M27, a gas cell 10 filled with a sample for spectroscopy, and a 4K-Si bolometer 11 for detecting **THz** wave.

* NOTICES *



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CLAIMS

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[Claim(s)]

[Claim 1] The spectrometer characterized by using the wavelength adjustable terahertz wave (terahertz parametric-below generating: TPG and abbreviation) obtained according to parametric generating (PG) which is a nonlinear optical effect as the light source.

[Claim 2] The spectrometer characterized by making into the light source in a small and powerful far infrared region the terahertz (Following THz and abbreviation) wave generated by exciting by the near-infrared light source in claim 1, using $LiNbO_3$ and $LiTaO_3$ grade as nonlinear crystal.

[Claim 3] The spectrometer characterized by having the light source which can carry out adjustable [ of the main wavelength of a THz wave produced from the inside of nonlinear crystal ] in claim 2 by changing whenever [ to the crystal of said excitation light source / incident angle ].

[Claim 4] The spectrometer characterized by having the light source with the description to which outgoing radiation of the THz wave is carried out in the about 1 direction even if it changes whenever [ to the crystal of the excitation light source / incident angle ] in claim 2 by using the prism made from Si for the ejection to the inside of the atmospheric air of the THz wave from nonlinear crystal.

[Claim 5] The small high brightness terahertz spectrophotometer characterized by combining the spectroscope using two beam interference with the wavelength adjustable TPG light source with strong spectral intensity.

[Claim 6] The spectrometer using the Martin-PAPURETTO mold fourier interferometer (a following MP mold interferometer and abbreviation) which used for the beam splitter the wire grid which has a transparency property with the sufficient effectiveness in a Submillimeter field in an interferometer in claim 5.

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[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the small high brightness terahertz spectrophotometer realized by combining the spectroscope using two beam interference with the wavelength adjustable TPG light source with the strong spectral intensity obtained according to parametric generating which is a nonlinear optical effect.
[0002]
[Description of the Prior Art] The high-pressure mercury-vapor lamp which has a continuous frequency component conventionally is used for the spectrum of a far infrared region as the almost only light source, and the advantageous Fourier transform spectrometer (Following FTS and abbreviation) using two beam interference is widely used in respect of the deployment of the quantity of light as a spectrometer. This uses that interference light reinforcement supports the Fourier transform from the wave number space of a light source spectrum to real space. They are the lamellar mold which acquires the 2 flux of lights comparatively more, and Martin who acquires the 2 flux of lights using polarization by the Michelson mold from which an FTS class acquires the 2 flux of lights amplitude splitting by the approach of acquiring the 2 flux of lights although divided light into the 2 flux of lights from the light source by the beam splitter, it was made to interfere after making the optical path difference between the 2 flux of lights, and the spectrum has been obtained from the interference curve in FTS, and the wave front. - It is divided roughly into three sorts of a PAPURETTO mold. In order that the effectiveness of the semitransparent mirror of the submillimeter field Michelson mold FTS may fall in this, many MP mold interferometers with an efficient transparency property are used.
[0003]
[Problem(s) to be Solved by the Invention] With the conventional far infrared exterior division light, since the spectral intensity of the high-pressure mercury-vapor lamp which is the light source is low, there is a fault that an overall S/N ratio will fall [ interferogram information ], including a noise mostly. It aims at the ability to measure the spectrum in this THz field (0.5-5THz) with sufficient S/N.
[0004]
[Means for Solving the Problem] In order to solve the above-mentioned technical problem, the following terahertz spectrophotometers were used for this invention. namely, the wavelength adjustable obtained according to parametric generating according to claim 1 -- it is the small high brightness terahertz spectrophotometer realized by combining it with the spectroscope using two beam interference as it is in claim 5, using TPG as the light source. TPG generated by exciting the nonlinear crystal LiNbO3 according to claim 2 and LiTaO3 grade by the near-infrared light source was used for the light source. Since this is wavelength adjustable, and is the pulse of nsec width of face in a large far infrared region and it has comparatively strong reinforcement, the long optical path length, and broadcloth spectral characteristics, it has the description advantageous to a spectrum and can serve as the light source in a small and powerful far infrared region. Furthermore, as a method of a spectrum, having considered the deployment of the quantity of light in a far infrared region, the fourier spectrometer using two beam interference was desirable, and the configuration of MP mold interferometer according to claim 6 which has a transparency property especially with the sufficient effectiveness in a Submillimeter field especially was used.
[0005]
[Embodiment of the Invention] Hereafter, the gestalt of this invention is explained with reference to a drawing. This invention is a small high brightness terahertz spectrophotometer realized by combining MP mold interferometer with the wavelength adjustable TPG light source, as indicated to claim 5. Here, each principle is shown.
A. In the generating principle light parametric interaction of THz wave parametric generating (TPG), when incidence of the pump wave (omegaP) omegaP is carried out to a nonlinear optical crystal according to claim 2, a signal wave (omegaT) and an idler (omegai) are the phenomena generated according to law-of-conservation-of-energy omega

P=omega T+omega i, and it becomes possible by extending the frequency of signal wave omegaT even to THz wave band to offer the light source with the broad spectrum suitable for a spectrum. When wavelength conversion of the light wave using a parametric interaction according to claim 1 performs THz wave generating, when the interaction of only a pure light wave is used, gain is small, and actuation of THz wave band is difficult. however, Raman active [, such as said LiNbO3, LiTaO3, etc., ] and infrared light -- if this activity non-linear optical material is used, a strong interaction can be started through the elementary excitation wave (PORARITON) of the matter. In a low energy field, as shown in drawing 1, if strong sufficient excitation light source according to claim 2 is used in order [ photon ] to act and carry out, PORARITON causes the induction scattering phenomenon through PORARITON, and the efficient outbreak of a THz wave (omegaT) is possible for it. The schematic diagram of the TPG experiment to drawing 2 is shown. When incidence of the pump light is carried out into a crystal, the quantum noise (thermal noise) generated at the incidence edge is amplified by crystal gain, and the light (idler light) which the frequency shifted from pump light is outputted. And a THz wave occurs in the place where pump light and idler light filled the law of conservation of energy (omega P=omegai+omegaT) and a law of conservation of momentum (kP=ki+kT). The THz wave to generate has a broad spectrum (about 15cm- 1) depending on a light-receiving angle, and can align main wavelength by changing the incident angle of a crystal. Drawing 3 is as a result of [ of the gain at the time of exciting non dope LiNbO3 crystal with the wavelength of 1.064 micrometers ] count, and it turns out that it has high gain in an about 150-400-micrometer field. The property that a gain coefficient increases with the pump light reinforcement IP originates in gain being proportional to the square root of IP. Moreover, the property that a gain coefficient increases in a low-temperature field originates mainly in reduction of the absorption coefficient in THz wave band.

B. The configuration of MP mold interferometer of principle claim 6 publication of the Martin-PAPURETTO mold interferometer is shown in drawing 4. In said MP mold interferometer, the polarization division method which divides the polarization direction of incident light and builds the two flux of lights is used. A wire grid according to claim 6 reflects the electromagnetic wave of the parallel polarization direction to this the wire, and makes a vertical electromagnetic wave penetrate ( drawing 5 ). That is, it has the description that it is possible to set reflective:transparency of an incidence electromagnetic wave to 1:1, and division of an efficient electromagnetic wave can be performed, by leaning said wire grid to 45 degrees to the polarization direction of an electromagnetic wave. The direction of polarization of the THz wave which carries out incidence is vertical to space. A THz wave is divided into 1:1 by the beam splitter D of said wire grid set at 45 degrees according to claim 6. It is reflected by a fixed mirror and the movable mirror and the polarization direction rotates the reflected light and 90 degrees of transmitted lights, respectively. The THz wave again combined by D is divided into a component vertical to a component parallel to this wire by Polarizer P (wire grid). The electric field which carry out incidence to said beam splitter are [formulas 1].

$$E_t = e_n \frac{a}{\sqrt{2}} \cos \omega t + e_t \frac{a}{\sqrt{2}} \cos \omega t \quad \cdots (1)$$

The electric field again combined by said beam splitter are [formulas 2].

$$E_j = e_n \frac{a}{\sqrt{2}} \cos(\omega t + \Delta_A) + e_t \frac{a}{\sqrt{2}} \cos(\omega t + \Delta_B) \quad \cdots (2)$$

The amplitude is as follows when outgoing radiation is carried out from a next door and said polarizer P.
[Formula 3]

$$|E| = \frac{a}{2}(\cos(\omega t + \Delta_A) - \cos(\omega t + \Delta_B)) \quad \cdots (3)$$

However, delta A and delta B are each phase change, and the reinforcement is [a formula 4].

$$I_P = \langle |E|^2 \rangle = \frac{a^2}{4}(1 - \cos\Delta) = \frac{I_0}{2}(1 - \cos\Delta) \quad \cdots (4)$$

It becomes. The optical path difference and sigma of delta=2pisigmax and x are the wave numbers here. When the spectral intensity is set to B (sigma), full strength is [a formula 5] by finding the integral about all sigma.

$$I(x) = \frac{1}{2}\int_0^\infty B(\sigma)(1 - \cos 2\pi\sigma x)\,d\sigma \quad \cdots (5)$$

It becomes. If the optical path difference x is changed, on-the-strength I (x) will change. This interference wave form is called an interferogram, and if the Fourier transform of the obtained interferogram is carried out, Spectrum B (sigma) will be called for. Since the terahertz spectrophotometer of this invention is based also on such fourier transform spectroscopy, it has the advantage which can measure many frequency components simultaneously.

[0006]

[Example] By combining the TPG light source and MP mold interferometer which were described until now, a

terahertz spectrophotometer with big spectral intensity is realizable. It depends for the transparency property of MP mold spectrometer on the reflective transparency property of a wire grid according to claim 6 greatly. If the wire grid used as said beam splitter sets spacing of a wire to g, effectiveness will fall on the wavelength of 4g or less. since the THz wave wavelength by TPG of this invention according to claim 1 is the band of 33cm-1-71cm-1 (140 micrometers - 310 micrometers) -- the spectrum of this invention -- the wire spacing g of a system (micrometer) is required for 35 micrometers or less so that this field may be first carried out by measurement. The diameter consisted of tungsten wires 10 micrometers and whose lattice spacings are 25 micrometers and 30 micrometers, respectively, and the lattice plane effective diameter of said wire grid is 90mm. Since a beam diameter is about 15mm in the location of about 5mm, the breadth include angle of about 1.5 degrees, and said beam splitter, the beam diameter of the THz light source generated from TPG of claim 1 has sufficient effective area. The system configuration of the terahertz spectrophotometer of this invention is shown in drawing 6 . The TPG light source of claim 1 used for THz wave generating is excited as near-infrared laser according to claim 2 by Nd:YAG laser (pulse energy 12mJ, 7ns of pulse width), and the generated THz wave is emitted to space using Si prism according to claim 4, after collimating it in an off-axis-paraboloid mirror, it is made into the linearly polarized light with a polarizer P1, and it is led to MP mold interferometer according to claim 6. The reflecting mirror used for the fixed mirror M1 and the movable mirror M2 uses the right-angle reflecting mirror with which a set of two rectangular prisms were aligned, and has performed coating of aluminum. It is adjusted so that an incidence electromagnetic wave can always be returned in the direction of incidence by this. Since this reflected light has the polarization of incident light, and the polarization which goes direct, it piles up again by the beam splitter. The actuators which make a movable mirror drive are the minimum migration spacing of 10 micrometers, and the 20cm of the maximum travels. 4 K-Si bolometer with high sensibility according to claim 7 was used for detection of a THz wave in which it interfered. SU ** KUTORU information is acquired by carrying out the Fourier transform of the signal wave form (interferogram) acquired by scanning a movable mirror. The terahertz spectrophotometer system of this invention performed the scan of a movable mirror, and automatic incorporation of the output data of a detector using the software for appliance control. The measurement procedure of an interferogram is as follows. Introduction, movable distance, and a sampling period are inputted, and the field of resolution and the wave number is decided. Next, after it moves delivery and a movable mirror for a computer to an instruction to the sampling starting position xi and a mirror arrives at xi, an oscilloscope is downloaded for the output from a detector to a through computer. then, the sampling starting position xi of the movable mirror begun after moving a movable mirror to the following location xi+1 again -- xi+ -- it obtains in every one and a subsequent process is acquired for the count repeat interferogram of the need. Each of above measurement and Fourier transform of an interferogram was processed on the computer, and has acquired SU ** KUTORU information.

[0007]

[Effect of the Invention] As explained above, the example of measurement of the terahertz spectrophotometer of this invention is shown. the max of spectrum measurement -- what is necessary is just to measure an interferogram by making the location of the optical path difference 0 into the starting point so that the maximum optical path difference may be acquired in order to obtain resolution Drawing 7 is an example of the interferogram of the THz wave measured in atmospheric air. In this measurement, in order to perform measurement to the a maximum of 100cm-1 (3THz) neighborhood, the sampling period was set as deltaX=40micrometer (number 125cmof maximum waves- 1). Moreover, the maximum optical path difference is set as 1cm, and the resolution corresponding to this is 0.5cm-1 (15GHz). Drawing 8 R> 8 is the spectrum obtained by the Fourier transform of an interferogram, and the whole envelope gives the spectral intensity of the THz light source. Said this main wavelength of TPG can align in 0.5-5THz.

[0008] thus, a high resolution spectrum [ in / THz band parametric generating light is carried out with MP mold terahertz spectrophotometer system made into the light source with the spectrum in the 0.5-5THz band by which it was not avoided that the spectral intensity of the light source runs short conventionally, and / THz wave band ] -- possible ** -- it is -- it can become ** 1 technique.

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[Translation done.]

* NOTICES *



## TECHNICAL FIELD

[The technical field to which invention belongs] This invention relates to the small high brightness terahertz spectrophotometer realized by combining the spectroscope using two beam interference with the wavelength adjustable TPG light source with the strong spectral intensity obtained according to parametric generating which is a nonlinear optical effect.

[Translation done.]

## PRIOR ART

[Description of the Prior Art] The high-pressure mercury-vapor lamp which has a continuous frequency component conventionally is used for the spectrum of a far infrared region as the almost only light source, and the advantageous Fourier transform spectrometer (Following FTS and abbreviation) using two beam interference is widely used in respect of the deployment of the quantity of light as a spectrometer. This uses that interference light reinforcement supports the Fourier transform from the wave number space of a light source spectrum to real space. They are the lamellar mold which acquires the 2 flux of lights comparatively more, and Martin who acquires the 2 flux of lights using polarization by the Michelson mold from which an FTS class acquires the 2 flux of lights amplitude splitting by the approach of acquiring the 2 flux of lights although divided light into the 2 flux of lights from the light source by the beam splitter, it was made to interfere after making the optical path difference between the 2 flux of lights, and the spectrum has been obtained from the interference curve in FTS, and the wave front. - It is divided roughly into three sorts of a PAPURETTO mold. In order that the effectiveness of the semitransparent mirror of the submillimeter field Michelson mold FTS may fall in this, many MP mold interferometers with an efficient transparency property are used.

[Translation done.]

* NOTICES *



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EFFECT OF THE INVENTION

---

[Effect of the Invention] As explained above, the example of measurement of the terahertz spectrophotometer of this invention is shown. the max of spectrum measurement -- what is necessary is just to measure an interferogram by making the location of the optical path difference 0 into the starting point so that the maximum optical path difference may be acquired in order to obtain resolution Drawing 7 is an example of the interferogram of the THz wave measured in atmospheric air. In this measurement, in order to perform measurement to the a maximum of 100cm-1 (3THz) neighborhood, the sampling period was set as deltaX=40micrometer (number 125cmof maximum waves- 1). Moreover, the maximum optical path difference is set as 1cm, and the resolution corresponding to this is 0.5cm-1 (15GHz). Drawing 8 R> 8 is the spectrum obtained by the Fourier transform of an interferogram, and the whole envelope gives the spectral intensity of the THz light source. Said this main wavelength of TPG can align in 0.5-5THz.
[0008] thus, a high resolution spectrum [ in / THz band parametric generating light is carried out with MP mold terahertz spectrophotometer system made into the light source with the spectrum in the 0.5-5THz band by which it was not avoided that the spectral intensity of the light source runs short conventionally, and / THz wave band ] -- possible ** -- it is -- it can become ** 1 technique.

---

[Translation done.]

* NOTICES *



## TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] With the conventional far infrared exterior division light, since the spectral intensity of the high-pressure mercury-vapor lamp which is the light source is low, there is a fault that an overall S/N ratio will fall [ interferogram information ], including a noise mostly. It aims at the ability to measure the spectrum in this THz field (0.5-5THz) with sufficient S/N.

[Translation done.]

* NOTICES *



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MEANS

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[Means for Solving the Problem] In order to solve the above-mentioned technical problem, the following terahertz spectrophotometers were used for this invention. namely, the wavelength adjustable obtained according to parametric generating according to claim 1 -- it is the small high brightness terahertz spectrophotometer realized by combining it with the spectroscope using two beam interference as it is in claim 5, using TPG as the light source. TPG generated by exciting the nonlinear crystal $LiNbO_3$ according to claim 2 and $LiTaO_3$ grade by the near-infrared light source was used for the light source. Since this is wavelength adjustable, and is the pulse of nsec width of face in a large far infrared region and it has comparatively strong reinforcement, the long optical path length, and broadcloth spectral characteristics, it has the description advantageous to a spectrum and can serve as the light source in a small and powerful far infrared region. Furthermore, as a method of a spectrum, having considered the deployment of the quantity of light in a far infrared region, the fourier spectrometer using two beam interference was desirable, and the configuration of MP mold interferometer according to claim 6 which has a transparency property especially with the sufficient effectiveness in a Submillimeter field especially was used.
[0005]
[Embodiment of the Invention] Hereafter, the gestalt of this invention is explained with reference to a drawing. This invention is a small high brightness terahertz spectrophotometer realized by combining MP mold interferometer with the wavelength adjustable TPG light source, as indicated to claim 5. Here, each principle is shown.
A. In the generating principle light parametric interaction of THz wave parametric generating (TPG), when incidence of the pump wave (omegaP) omegaP is carried out to a nonlinear optical crystal according to claim 2, a signal wave (omegaT) and an idler (omegai) are the phenomena generated according to law-of-conservation-of-energy omega P=omega T+omega i, and it becomes possible by extending the frequency of signal wave omegaT even to THz wave band to offer the light source with the broad spectrum suitable for a spectrum. When wavelength conversion of the light wave using a parametric interaction according to claim 1 performs THz wave generating, when the interaction of only a pure light wave is used, gain is small, and actuation of THz wave band is difficult. however, Raman active [, such as said $LiNbO_3$, $LiTaO_3$, etc., ] and infrared light -- if this activity non-linear optical material is used, a strong interaction can be started through the elementary excitation wave (PORARITON) of the matter. In a low energy field, as shown in drawing 1, if strong sufficient excitation light source according to claim 2 is used in order [ photon ] to act and carry out, PORARITON causes the induction scattering phenomenon through PORARITON, and the efficient outbreak of a THz wave (omegaT) is possible for it. The schematic diagram of the TPG experiment to drawing 2 is shown. When incidence of the pump light is carried out into a crystal, the quantum noise (thermal noise) generated at the incidence edge is amplified by crystal gain, and the light (idler light) which the frequency shifted from pump light is outputted. And a THz wave occurs in the place where pump light and idler light filled the law of conservation of energy (omega P=omegai+omegaT) and a law of conservation of momentum (kP=ki+kT). The THz wave to generate has a broad spectrum (about 15cm- 1) depending on a light-receiving angle, and can align main wavelength by changing the incident angle of a crystal. Drawing 3 is as a result of [ of the gain at the time of exciting non dope $LiNbO_3$ crystal with the wavelength of 1.064 micrometers ] count, and it turns out that it has high gain in an about 150-400-micrometer field. The property that a gain coefficient increases with the pump light reinforcement IP originates in gain being proportional to the square root of IP. Moreover, the property that a gain coefficient increases in a low-temperature field originates mainly in reduction of the absorption coefficient in THz wave band.
B. The configuration of MP mold interferometer of principle claim 6 publication of the Martin-PAPURETTO mold interferometer is shown in drawing 4. In said MP mold interferometer, the polarization division method which divides the polarization direction of incident light and builds the two flux of lights is used. A wire grid according to claim 6 reflects the electromagnetic wave of the parallel polarization direction to this the wire, and makes a vertical electromagnetic wave penetrate ( drawing 5 ). That is, it has the description that it is possible to set reflective:transparency of an incidence electromagnetic wave to 1:1, and division of an efficient electromagnetic wave

can be performed, by leaning said wire grid to 45 degrees to the polarization direction of an electromagnetic wave. The direction of polarization of the THz wave which carries out incidence is vertical to space. A THz wave is divided into 1:1 by the beam splitter D of said wire grid set at 45 degrees according to claim 6. It is reflected by a fixed mirror and the movable mirror and the polarization direction rotates the reflected light and 90 degrees of transmitted lights, respectively. The THz wave again combined by D is divided into a component vertical to a component parallel to this wire by Polarizer P (wire grid). The electric field which carry out incidence to said beam splitter are [formulas 1].

$$E_t = e_n \frac{a}{\sqrt{2}} \cos \omega t + e_t \frac{a}{\sqrt{2}} \cos \omega t \quad \cdots (1)$$

The electric field again combined by said beam splitter are [formulas 2].

$$E_j = e_n \frac{a}{\sqrt{2}} \cos(\omega t + \Delta_A) + e_t \frac{a}{\sqrt{2}} \cos(\omega t + \Delta_B) \quad \cdots (2)$$

The amplitude is as follows when outgoing radiation is carried out from a next door and said polarizer P.
[Formula 3]

ID=000005

However, delta A and delta B are each phase change, and the reinforcement is [a formula 4].

$$I_P = \langle |E|^2 \rangle = \frac{a^2}{4}(1 - \cos \Delta) = \frac{I_0}{2}(1 - \cos \Delta) \quad \cdots (4)$$

It becomes. The optical path difference and sigma of delta=2pisigmax and x are the wave numbers here. When the spectral intensity is set to B (sigma), full strength is [a formula 5] by finding the integral about all sigma.

$$I(x) = \frac{1}{2} \int_0^\infty B(\sigma)(1 - \cos 2\pi\sigma x) d\sigma \quad \cdots (5)$$

It becomes. If the optical path difference x is changed, on-the-strength I (x) will change. This interference wave form is called an interferogram, and if the Fourier transform of the obtained interferogram is carried out, Spectrum B (sigma) will be called for. Since the terahertz spectrophotometer of this invention is based also on such fourier transform spectroscopy, it has the advantage which can measure many frequency components simultaneously.

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[Translation done.]

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## EXAMPLE

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[Example] By combining the TPG light source and MP mold interferometer which were described until now, a terahertz spectrophotometer with big spectral intensity is realizable. It depends for the transparency property of MP mold spectrometer on the reflective transparency property of a wire grid according to claim 6 greatly. If the wire grid used as said beam splitter sets spacing of a wire to g, effectiveness will fall on the wavelength of 4g or less. since the THz wave wavelength by TPG of this invention according to claim 1 is the band of 33cm-1-71cm-1 (140 micrometers - 310 micrometers) -- the spectrum of this invention -- the wire spacing g of a system (micrometer) is required for 35 micrometers or less so that this field may be first carried out by measurement. The diameter consisted of tungsten wires 10 micrometers and whose lattice spacings are 25 micrometers and 30 micrometers, respectively, and the lattice plane effective diameter of said wire grid is 90mm. Since a beam diameter is about 15mm in the location of about 5mm, the breadth include angle of about 1.5 degrees, and said beam splitter, the beam diameter of the THz light source generated from TPG of claim 1 has sufficient effective area. The system configuration of the terahertz spectrophotometer of this invention is shown in drawing 6 . The TPG light source of claim 1 used for THz wave generating is excited as near-infrared laser according to claim 2 by Nd:YAG laser (pulse energy 12mJ, 7ns of pulse width), and the generated THz wave is emitted to space using Si prism according to claim 4, after collimating it in an off-axis-paraboloid mirror, it is made into the linearly polarized light with a polarizer P1, and it is led to MP mold interferometer according to claim 6. The reflecting mirror used for the fixed mirror M1 and the movable mirror M2 uses the right-angle reflecting mirror with which a set of two rectangular prisms were aligned, and has performed coating of aluminum. It is adjusted so that an incidence electromagnetic wave can always be returned in the direction of incidence by this. Since this reflected light has the polarization of incident light, and the polarization which goes direct, it piles up again by the beam splitter. The actuators which make a movable mirror drive are the minimum migration spacing of 10 micrometers, and the 20cm of the maximum travels. 4 K-Si bolometer with high sensibility according to claim 7 was used for detection of a THz wave in which it interfered. SU ** KUTORU information is acquired by carrying out the Fourier transform of the signal wave form (interferogram) acquired by scanning a movable mirror. The terahertz spectrophotometer system of this invention performed the scan of a movable mirror, and automatic incorporation of the output data of a detector using the software for appliance control. The measurement procedure of an interferogram is as follows. Introduction, movable distance, and a sampling period are inputted, and the field of resolution and the wave number is decided. Next, after it moves delivery and a movable mirror for a computer to an instruction to the sampling starting position xi and a mirror arrives at xi, an oscilloscope is downloaded for the output from a detector to a through computer. then, the sampling starting position xi of the movable mirror begun after moving a movable mirror to the following location xi+1 again -- xi+ -- it obtains in every one and a subsequent process is acquired for the count repeat interferogram of the need. Each of above measurement and Fourier transform of an interferogram was processed on the computer, and has acquired SU ** KUTORU information.

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[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the dispersion relation and the phase matching curve of PORARITON.
[Drawing 2] It is the block diagram of a THz parametric generating experiment.
[Drawing 3] It is drawing showing the frequency characteristics of parametric gain.
[Drawing 4] It is the block diagram of the Martin-PAPURETTO mold interferometer.
[Drawing 5] It is drawing showing the polarization property of a wire grid.
[Drawing 6] It is the block diagram of the whole terahertz spectrophotometer.
[Drawing 7] It is drawing of the interferogram of the THz wave measured among atmospheric air with the terahertz spectrophotometer.
[Drawing 8] It is drawing showing the spectrum after the Fourier transform by the computer.
[Description of Notations]
1 Excitation Laser
2 Coupler
3 Nonlinear Crystal
4 Distributor
5 The Polarization Version
6 Fixed Mirror
7 Operation Mirror
8 Wire
9 Unsymmetrical Spherical-Surface Mirror for Collimation
10 Spectrum -- ** Data
11 Detector
12 Controller for Operation Mirrors
13 Oscilloscope
14 Computer for System Controls
15 Terahertz Spectrophotometer

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[Translation done.]

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## DRAWINGS

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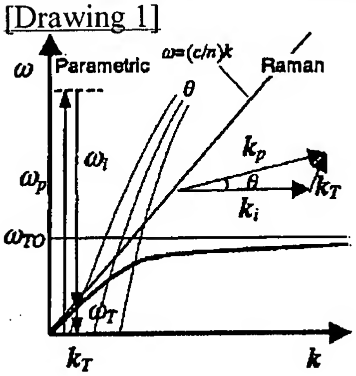
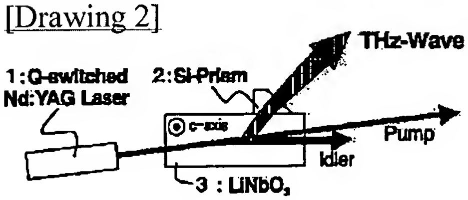
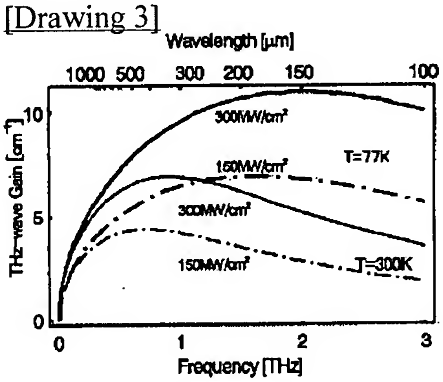
[Drawing 1]



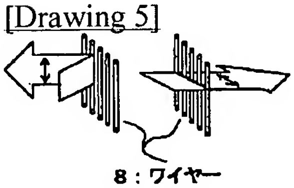

[Drawing 2]




[Drawing 3]




[Drawing 5]

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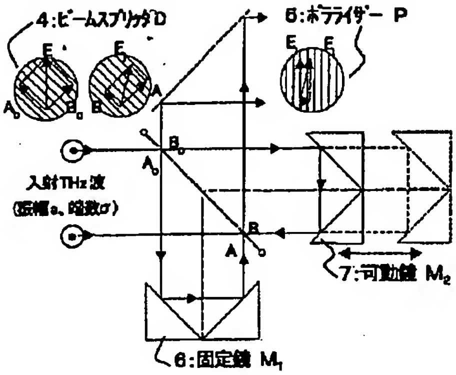
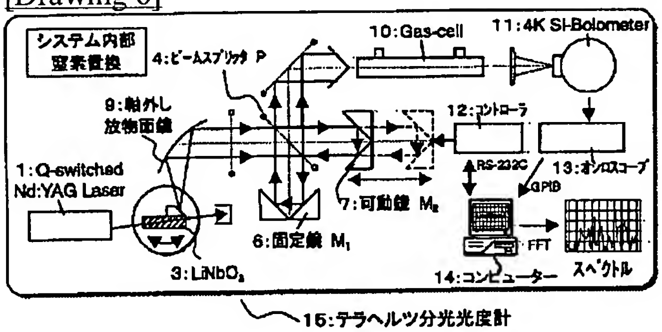
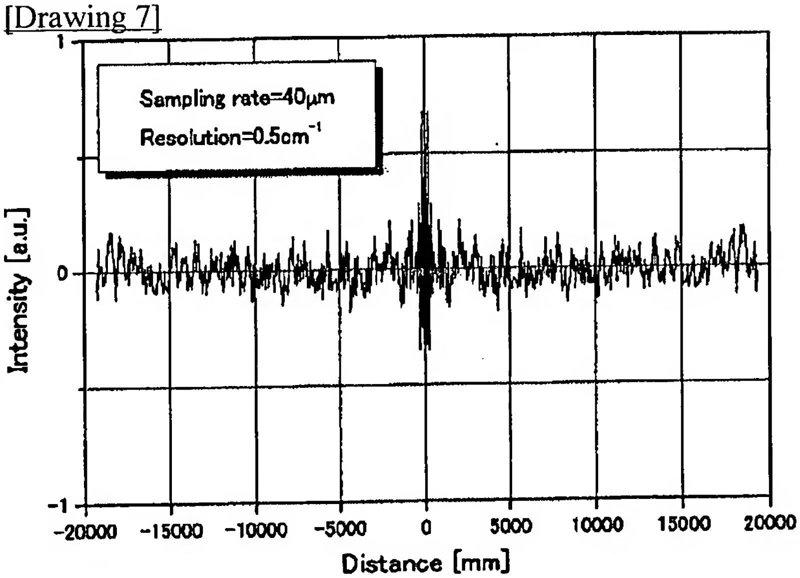


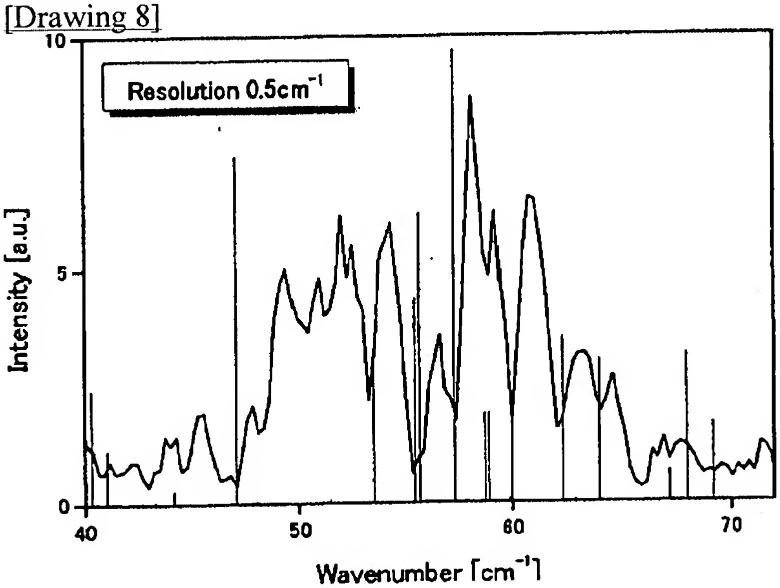

[Drawing 6]




[Drawing 7]




[Drawing 8]



[Translation done.]